SCENARIOS OF FUTURE FERTILITY DEVELOPMENT IN THE CZECH REPUBLIC BASED ON THE FUNCTIONAL DEMOGRAPHIC MODEL

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Abstract

The paper deals with the issue of modelling the development of fertility in the Czech Republic in the future. The calculation of several scenarios is performed using the Functional demographic model, which is often used abroad. The first part is devoted to a brief introduction of the model used in the paper and the second to the results of the projection itself. The projection is performed in three scenarios, it is a low, medium and high variant. As another criterion for dividing scenarios, the length of the modelled time series of age-specific fertility rates is chosen. The projection is made for ten years ahead, specifically the paper shows the estimated values for 2025 and 2030. The differences between the individual scenarios are compared and, at the same time, a comparison is made with the current Eurostat projection. The results show that the length of the modelled time series plays a key role in projecting the future development of fertility. It turns out that, with the exception of the low variant and the variant of modelling time series since 1989, the Functional demographic model tends to be more optimistic about estimating future values of the total fertility rate than Eurostat's assumptions.

Key words: fertility, demographic projection, time series

JEL Code: J11, J13

Introduction

Recently there has been a growing interest in the modelling of age-specific fertility rates and the total fertility rate (see Roubíček, 1997), especially with regards to low fertility rates in countries after the second demographic transition (Van De Kaa, 1987).

One of the models often used in foreign publications includes the Functional Demographic Approach (Hyndman, Ullah, 2007). When analysing the national data, it is

obvious that this model has been mentioned in publications in the Czech Republic only sporadically (e.g. Hon, 2020).

This article uses the aforesaid model to estimate potential scenarios of the fertility trend in the Czech Republic for the next ten years, assuming that the current trend will continue. This article presents nine potential scenarios that the model suggests and compares them with Eurostat's current projection.

The first part of this article includes a very brief methodological description of the Functional Demographic Model. The second part focuses on the individual scenarios specified for the projection purposes, on their results and comparison.

1 Functional demographic model

This section is devoted to a very brief introduction of used model for projection of age-specific fertility rates and total fertility rate in this paper. Functional demographic model is an approach for modelling fertility curves using nonparametric smoothing and principal component analysis, it could be considered as an extension of well-known Lee-Carter model.

In mathematical notation, the main ideas of the model can be summarized in following formula. Time series is defined as $\{x_i, y_t(x_i)\}$, $t = 1, \ldots, n$, $i = 1, \ldots, p$ and $\{x_1, \ldots, x_p\}$ are single years of age.

$$y_t(x_i) = f_t(x_i) + \sigma_t(x_i)\varepsilon_{t,i} \qquad (1)$$

In formula 1, it is subsequently defined as $y_t(x)$ the log of the observed fertility rate and is forecasted for $x \in [x_1, x_p]$ and $t = n + 1, \ldots, n + h$. To the right of the equal sign $f_t(x_i)$ is an underlying smooth fertility function, σ_t represents in the model the variance and $\varepsilon_{t,i}$ is an iid standard normal random variable. For more detailed methodology, concerning in particular the estimation of future $f_t(x_i)$ values, please see related literature due to the fact that a complete methodological description would be very extensive (see Hyndman, Ullah, 2007).

2 Projection results

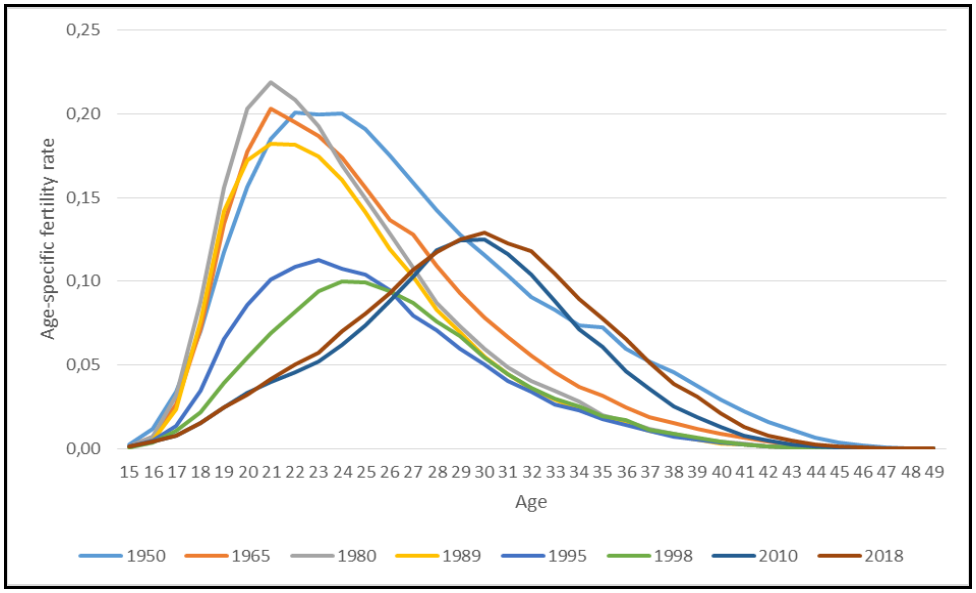
Based on the Functional Demographic Model described in the methodology, we estimated the age-specific fertility rates in the Czech Republic. This chapter describes the main results of this projection.

The projection was made based on data from the Human Fertility Database and includes three scenarios, i.e. a low, medium and high variant, depending on how optimistic the assumptions used in the model are. In other words, the low variant corresponds to the

lower limit and the high variant to the upper limit of the confidence interval. The length of the modelled time series of age-specific fertility rates is another criterion used to differentiate the individual scenarios. In the Czech Republic, an appropriately chosen length of the modelled time series is crucial for determining the demographic realness of the resulting projection (Šimpach, 2015). The first scenario works with the maximum length of the time series available in the Human Fertility Database, i.e. starting with the year 1950. The second scenario works with the time series starting with the year 1989; the political changes in 1989 triggered an accelerated second demographic transition in the 1990s in both the Czech Republic and other post-socialist countries (Sobotka et al., 2008; Van de Kaa, 2002). The third scenario works with the time series starting with the year 1998, which – taking into account the demographic development in the Czech Republic – is sometimes recommended in order to increase the realness of projections (Šimpach, 2015). The projection in this article is made for the next ten years, specifically for 2025 and 2030. This chapter discusses the differences among the individual scenarios and compares them with Eurostat's current projection called Europop 2019 (Eurostat, 2021).

The projection was made based on the code and recommendations contained in the RStudio application package "Demography" (Hyndman et al., 2019).

Fig. 1: Age-specific fertility rates in the selected years in the Czech Republic

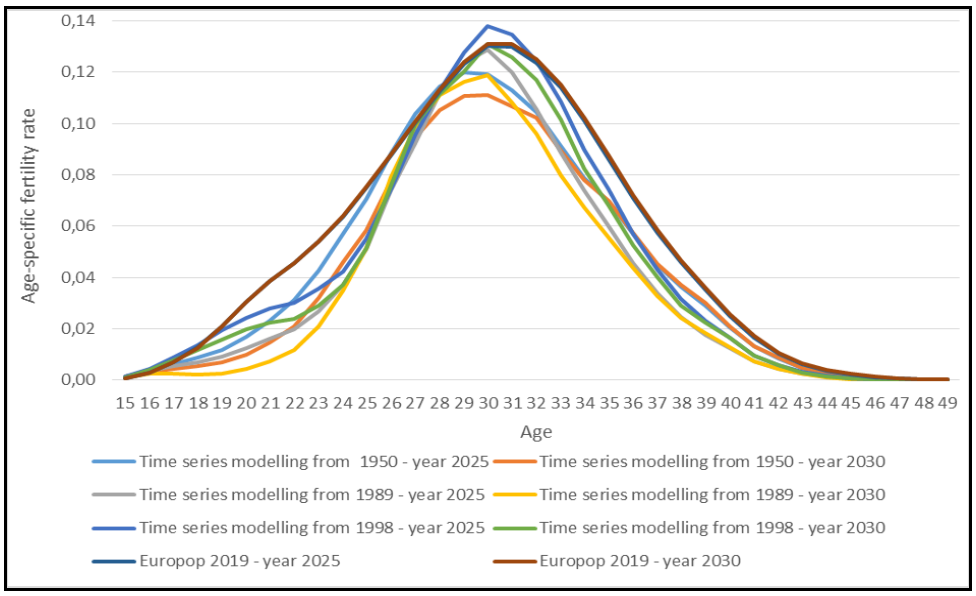


Source: Human Fertility Database, Eurostat, own processing

Age-specific fertility rates in the selected years are the first to be plotted in Figure 1. It begins with the year 1950, which is the very first year available in the Human Fertility Database. Subsequently, the data are plotted in 15-year age intervals to make it possible to analyse the main changes in fertility rates over time; the figure would be difficult to read if every year were included. The figure also includes the starting years of the individual projection scenarios.

We can see that fertility rates were significantly higher in the past than today and that reproduction occurred usually around the age of 20. The new political establishment brought about a change in society and major changes in the demographic behavior of the population (Sobotka et al., 2008). At the turn of the millennium, fertility rates were very low and reproduction began to gradually shift to an older age. We can see that the total fertility rate has gone up lately, although women reproduce at an older age much more often than they used to. The highest fertility rates are currently around the age of 30.

Fig. 2: Projected future age-specific fertility rates in the selected years in the Czech Republic – low variant



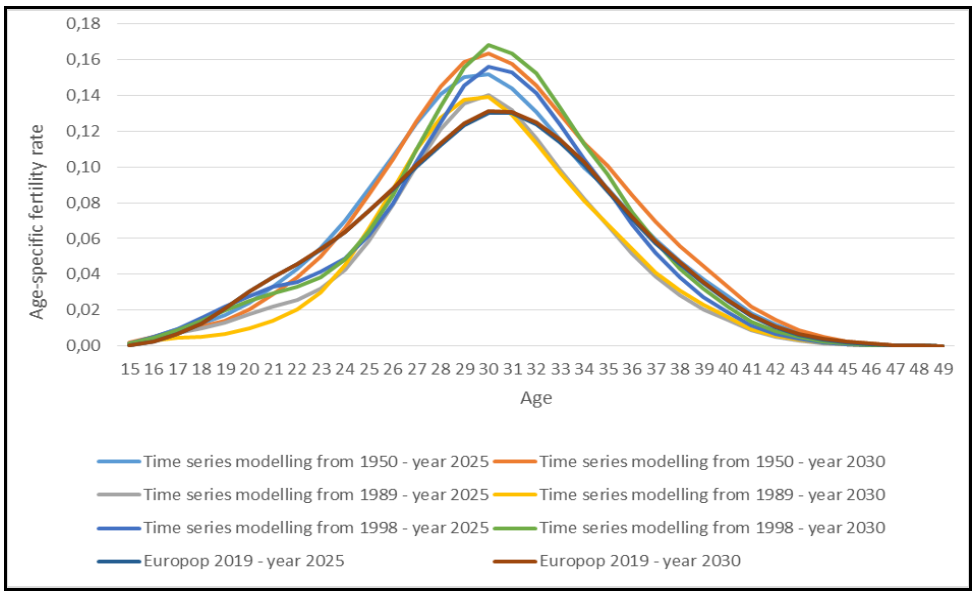
Source: Human Fertility Database, Eurostat, own processing

Figure 2 shows that Eurostat's projection in terms of expected age-specific fertility rates is rather pessimistic and relatively similar to the low variant of the projection made based on the Functional Demographic Model, however with a significant difference in fertility rate among women aged 35 and over, which Eurostat expects to be significantly higher than all low variant scenarios. According to Eurostat's projection, we cannot expect a significant shift in age-specific fertility rates between 2025 and 2030; both curves almost perfectly overlap.

As to the modal age of fertility, the scenario with the modelled time series starting with the year 1950 shows the lowest age-specific fertility rates. This scenario, contrary to other scenarios, does not expect such a significant further postponement of the population's reproduction. The shorter the time series that is modelled, the sharper the distribution of age-specific fertility rates.

The differences among the individual scenarios with a different length of the modelled time series are relatively significant.

Fig. 3: Projected future age-specific fertility rates in the selected years in the Czech Republic – medium variant

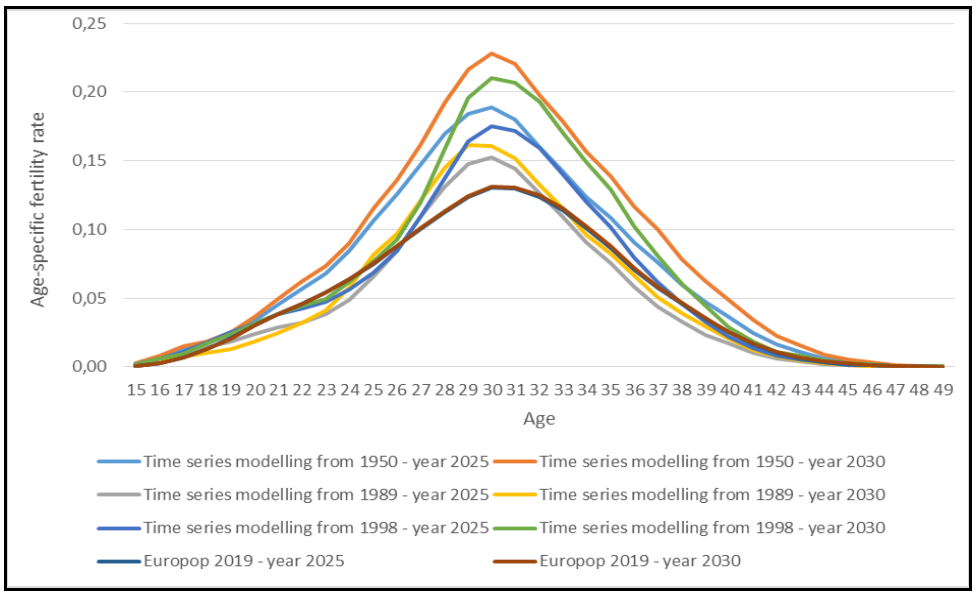


Source: Human Fertility Database, Eurostat, own processing

Figure 3, which depicts the medium variant of the projection and compares it with Eurostat's projection, shows a number of facts already found in the low variant of the projection. Again, we can see e.g. that the model estimates a further decline in fertility rates around the age of 20, with the exception of the scenario that models the time series starting with the year 1950.

The most pessimistic scenario is the one that models the time series starting with the year 1989. Contrary to Eurostat's projection, this scenario shows higher rates only around the modal age of fertility and is quite pessimistic with respect to other ages. The scenarios modelling the time series starting with the year 1950 and 1998 are rather optimistic and expect e.g. a relatively significant increase of the analysed characteristics in the modal age of fertility. The scenario modelling the time series starting with the year 1950 shows again a tendency towards relatively high fertility rates even at a younger age; we can see the same tendency in Eurostat's projection, but not in the other scenarios.

Fig. 4: Projected future age-specific fertility rates in the selected years in the Czech Republic – high variant



Source: Human Fertility Database, Eurostat, own processing

Figure 4, which depicts the high variant of the projection, shows again that the variant modelling the time series starting with the year 1989 is the most pessimistic out of the scenarios estimated based on the Functional Demographic Model. However, it is more optimistic in the modal age of fertility than Eurostat's projection.

The remaining scenarios show a rather significant increase in fertility rates between 2025 and 2030. The scenario modelling the time series starting with the year 1950 again assumes significantly higher fertility rates at a younger age than the other scenarios.

Tab. 1: Projected future total fertility rate in the selected years in the Czech Republic

Scenario	Time series modelling from 1950		Time series modelling from 1989		Time series modelling from 1998		Europop 2019	
	2025	2030	2025	2030	2025	2030	2025	2030
Low	1,5	1,4	1,3	1,2	1,5	1,4	1,7	1,8
Medium	1,9	2,0	1,5	1,5	1,8	1,9		
High	2,4	2,8	1,7	1,8	2,0	2,4		

Source: Human Fertility Database, Eurostat, own processing

Table 1 includes the projection of the total fertility rate in the selected years. We can see that the medium projection made based on the Functional Demographic Model is the

closest to both Eurostat's projection and the current projection of the Czech Statistical Office (Zeman, 2019).

The only exception is the scenario modelling the time series starting with the year 1989, which – as the graphs above have indicated – is highly pessimistic. In this case, the high variant is the closest to the projection of the total fertility rate according to Eurostat and the Czech Statistical Office.

On the other hand, the high variants of the projection of the remaining scenarios assume a rather unrealistic total fertility rate for the Czech Republic in 2030 from demographic point of view (see Van de Kaa, 1987).

Conclusion

The results of the projection made in this article show that the length of the modelled time series for the Czech Republic also plays a key role in projecting the future trend in fertility rates. It turned out that, with the exception of the low variant and the modelling of time series starting with the year 1989, the Functional Demographic Model tends to estimate more optimistic future fertility rates than those expected by Eurostat.

With the exception of the scenario modelling the time series starting with the year 1950, we can expect - based on the Functional Demographic Model - a further decrease in fertility rates at a younger age, an intensified postponement of reproduction to an older age and an increasing sharpness of the distribution of age-specific fertility rates. However, Eurostat's projection does not expect a similar change in the fertility rate curve.

In terms of the final total fertility rate, the medium variant of the projection in the scenarios modelling the time series starting with the year 1950 and 1998 was the closest to the present situation and Eurostat's projection. The high variant was the closest only in the entirely pessimistic scenario modelling the time series starting with the year 1989. On the other hand, the high variant in the other scenarios was unrealistically optimistic from a demographic point of view.

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